

Applications of SERI Science & Technology

Putting Waste to Work

New SERI Reactor Turns Solid Waste into Natural Gas

While most of the United States continues to build mounds of garbage, researchers at the Solar Energy Research Institute (SERI) have been digging for ways to turn that garbage into energy and profits for America. And they have come up with the right technology—a reactor that economically ferments municipal solid waste (MSW) to methane gas.

Today, we bury most of our MSW in landfills, an increasingly unacceptable method of disposal. Instead, using biological means (fermentation), we could turn a large part of that MSW into natural gas (methane). However, biological methods have been too slow or too expensive—until now.

SERI's new reactor, a high-solids fermenter (HSF), entails a simple design, uses low levels of power and water, and converts MSW to methane more rapidly and economically than conventional fermenters. All these are helping to make fermentation economically attractive.



Rather than bury our waste in landfills, SERI's innovative high-solids fermenter could help turn America's garbage into methane (natural gas) at a profit.

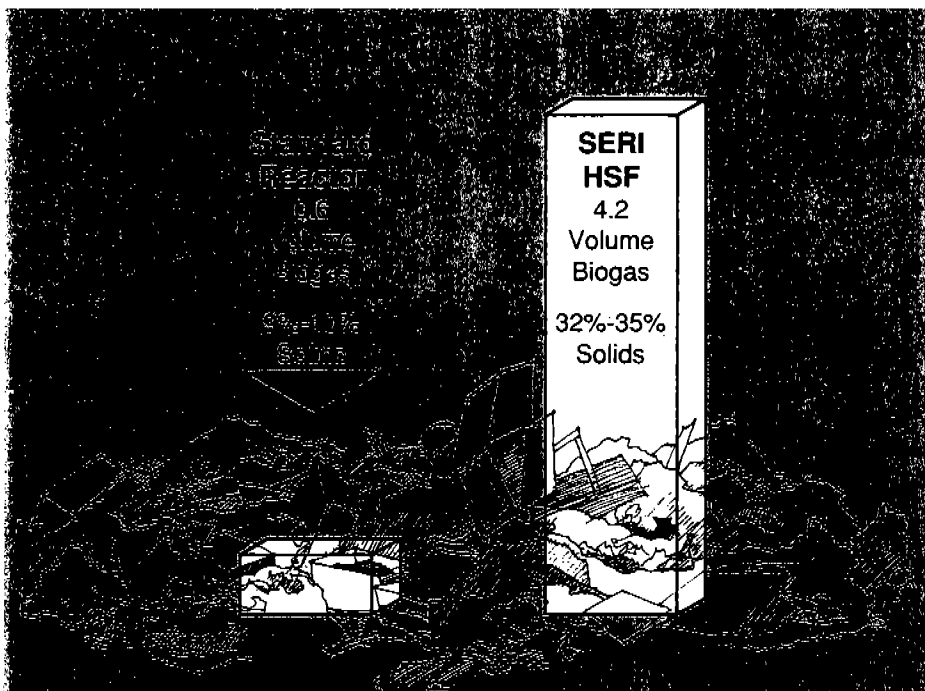
The Applications — Producing Methane

Fermentation reactors such as the HSF depend on anaerobic digestion (the bacterial decomposition of complex organic compounds in the absence of oxygen) to turn the biodegradable portion of MSW into methane. In a reactor, digestion is

typically accomplished by using a slurry—a mixture of solid organic material, water, and added nutrients and microbes. Because it is the solids that are being broken down into gas, the rate at which the gas is produced is proportional to the amount of solids in the slurry. In other words, higher percentages of solids in the slurry produce more gas.

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SERI used the HSF to determine that 32% to 35% is the optimum solids concentration level for the anaerobic digestion of MSW to biogas. At this level, the HSF produces 4.2 volumes of biogas daily for every volume of sludge. This is seven times more gas than is produced in conventional reactors, which can handle only up to 9% or 10% solids concentration in the slurry.

Decomposition is enhanced by maintaining a thorough mixture of slurry elements: solids, liquids, nutrients, and microbes.

Until SERI developed the HSF, fermenting MSW into methane cost too much because of the limitations of conventional fermentation reactors. Standard reactors are too large and their gas production rates are low. At solids concentrations any higher than about 9% or 10%, they do not mix slurry ingredients adequately. They often overheat some of the material, which can cause microbes to become inactive, while leaving the bulk of the material unmixed. They use large quantities of water for the amount of solids they can handle. And they operate at higher power levels as solids concentrations increase.

SERI's HSF overcomes these limitations. It is capable of mixing any concentration of solids, from 0% to 100%. Consequently, the HSF can handle an optimum concentration of solids while properly mixing the material, nutrients, and microbes.

This results in a high rate of gas production, reduces the amount of water needed for the slurry, lessens the amount of effluent water that

must be treated, and simplifies the disposal of effluent solids. These enable the HSF reactor to be smaller than other reactors and thus less expensive to own and operate.

That's not all. The HSF's unique design makes it able to adequately mix any slurry concentration without excessive shear, without overheating parts of the material, and without leaving some of the material stagnant. The design also enables the HSF to operate at low power.

The Results — Greater Gas Production

SERI researchers used several bench-scale experiments to prove the capabilities of their new reactor. In one crucial trial, they confirmed the reactor's proficiency in handling high concentrations of MSW while achieving high levels of gas production. In this experiment, they determined the maximal level of solids concentration needed to produce gas from MSW: 32% to 35% of the slurry mixture. At this concentration



SERI researchers are using four HSF units to digest MSW into methane gas. The units have run uninterrupted for more than two years.



The HSF consists of a cylindrical vessel with a horizontal axis along which the agitator shaft runs. Typical agitator blades are rods spaced at 90-degree angles around the shaft in a staggered manner. The rods extend radially from the shaft to near the vessel walls.

level, the HSF produces gas at a rate seven times that of the maximum rate of a conventional reactor.

In a related experiment, researchers operated four reactors continuously for more than two years, producing gas from MSW. In that time, the reactors were run at up to 80% of their maximum fermenter volume with a high rate of throughput of feed material. None of the reactors had to be shut down for any reason, establishing the HSF's ability to perform in a stable, sustained manner over long periods.

The gas produced by the reactors was about 65% methane and 35% carbon dioxide, a medium-Btu gas suitable for direct use as a boiler fuel or in other applications. The gas could also be cleaned to remove the carbon dioxide and any trace impurities to produce pipeline-quality gas.

The next R&D step is to take the HSF through pilot-scale demonstration to iron out difficulties before commercialization.

The Basics — Unique Design

The secret to the success of the HSF lies in its design.

A standard reactor uses a cylindrical vessel with a vertical axis. An agitator shaft is mounted along the axis with turbine or propeller blades

positioned at various points along the shaft. As the shaft rotates, at speeds up to 100 rpm (revolutions per minute) or more, the blades mix the reactor contents.

The SERI HSF, on the other hand, uses a cylindrical vessel with a horizontal axis, along which the agitator shaft is mounted. Although several designs are feasible for the blades attached to the shaft, the typical agitator configuration consists of a series of rods protruding radially from the shaft toward the vessel walls. The rods are positioned in four rows mounted at 90-degree angles to one another between adjacent rows around the shaft. The rods in each row are staggered

along the shaft with respect to the rods in the previous row so that, as the shaft turns, each rod sweeps out a distinct path from the rod mounted in the preceding row.

As a rod moves through the contents, it pushes the material aside in a manner similar to that we observe when hoeing a garden. As the rod in the next row follows, it moves through the fermenter contents, pushing the material aside and filling the furrow created by the preceding rod. In this fashion, with the agitator shaft turning at 1 rpm or less, the reactor gently and thoroughly blends the fermenter contents while minimizing the power required for mixing. The SERI HSF will successfully mix any material that moves under this type of action.

The Market — Methane from MSW

America produces approximately 200 million tons of MSW every year, much of which is deposited in landfills. From this waste, and from sewage sludge and other sources, we could recover more than 1.5 to 2.0 quads of energy every year, either by burning the waste or fermenting it to methane. With the HSF, we can do both. Once the gas has been fermented from the solid waste, the spent solids can be burned directly without the expense of removing

Other Applications

SERI's high-efficiency fermenter not only produces gas from MSW. The reactor is equally capable of producing gas from agricultural or food waste resources that could prove more abundant than MSW. In fact, the HSF can be used with any fermentation method that converts organic solids to organic gases. This means food by using wood, agricultural waste, corn or other crops, we could produce ammonia, ethanol, organic acids, ketones, and more.

Beyond that, we may eventually be able to use the HSF to produce antibiotics or enzymes from fungi, produce organic acids, health care and other products needed precisely using the appropriate microbial processes.

The reactor design makes all of these uses quite feasible technically. Its construction is simple and rugged. SERI is currently demonstrating the benefits of the HSF.

the water, which is required with a conventional fermenter.

The market value of such a resource is hard to pin down to exact dollars and cents, especially because the price of natural gas is tied to that of #2 and #6 heating oil, a volatile market. But under any circumstances, the market could run into billions of dollars per year, making the resource quite valuable. And when viewed from the perspectives of the environment, the stability of the resource, and the fact that the resource is regionally available, methane from MSW becomes

even more valuable, especially to industries and municipalities vulnerable to the vagaries of other supplies.

The HSF can be built in many sizes; costs decrease per unit of volume as device size increases. The estimated cost of a 20-liter fermenter, for example, is about \$3,000; a 40,000-liter fermenter, in contrast, should cost about \$225,000.

